CERES Overview

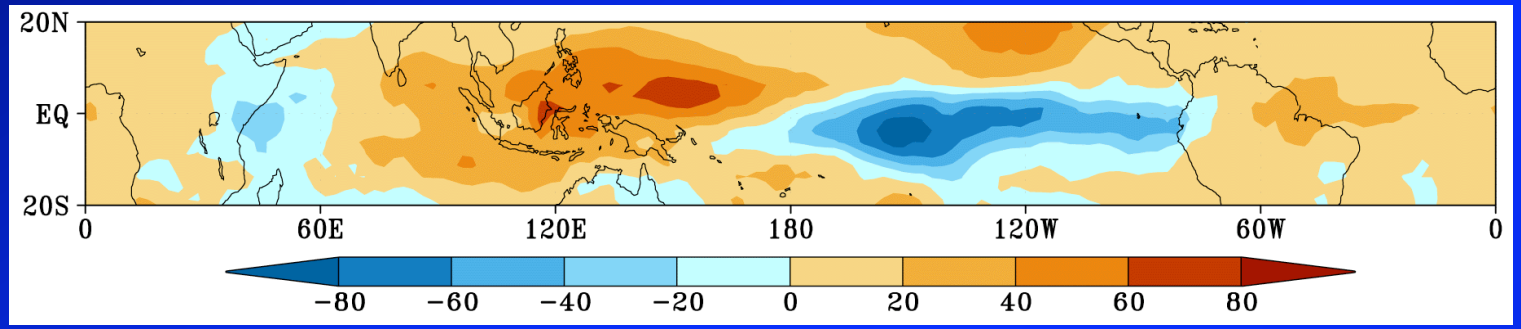
Bruce Wielicki

1st CERES-II Science Team Meeting
March 29-31, 2005
NCAR, Boulder, CO

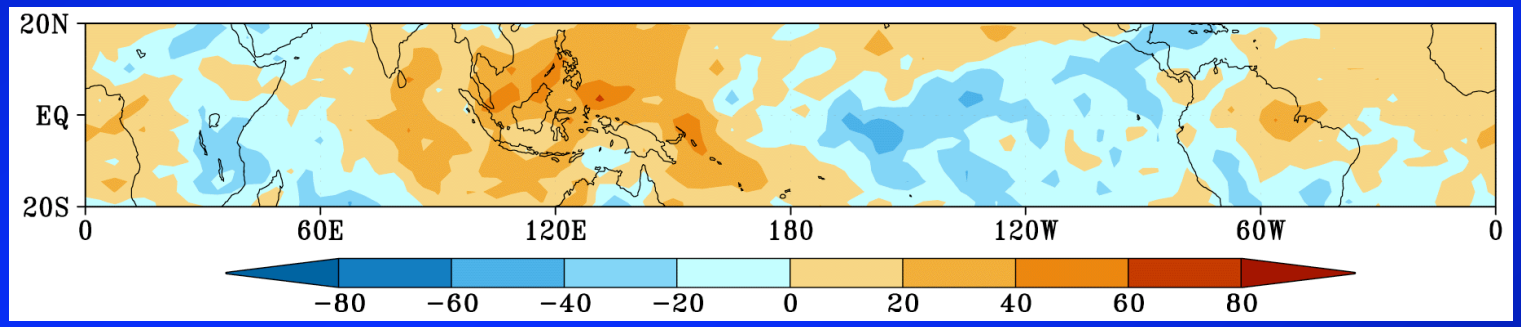
Jan/Feb 98 El Nino TOA LW Flux Anomalies

(relative to ERBE 1985-1989 average)

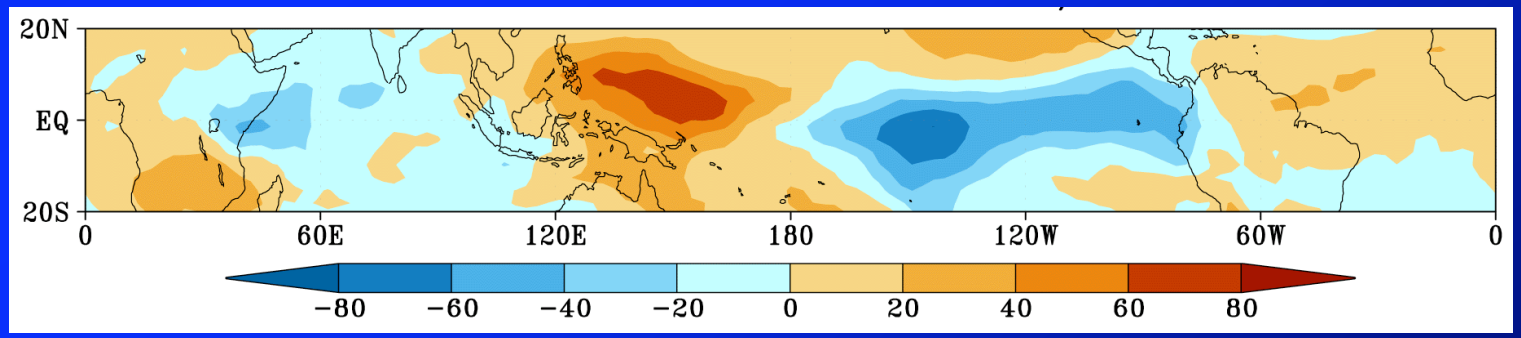
CERES ERBE-Like LW Flux Observations



NOAA GFDL Standard Climate Model

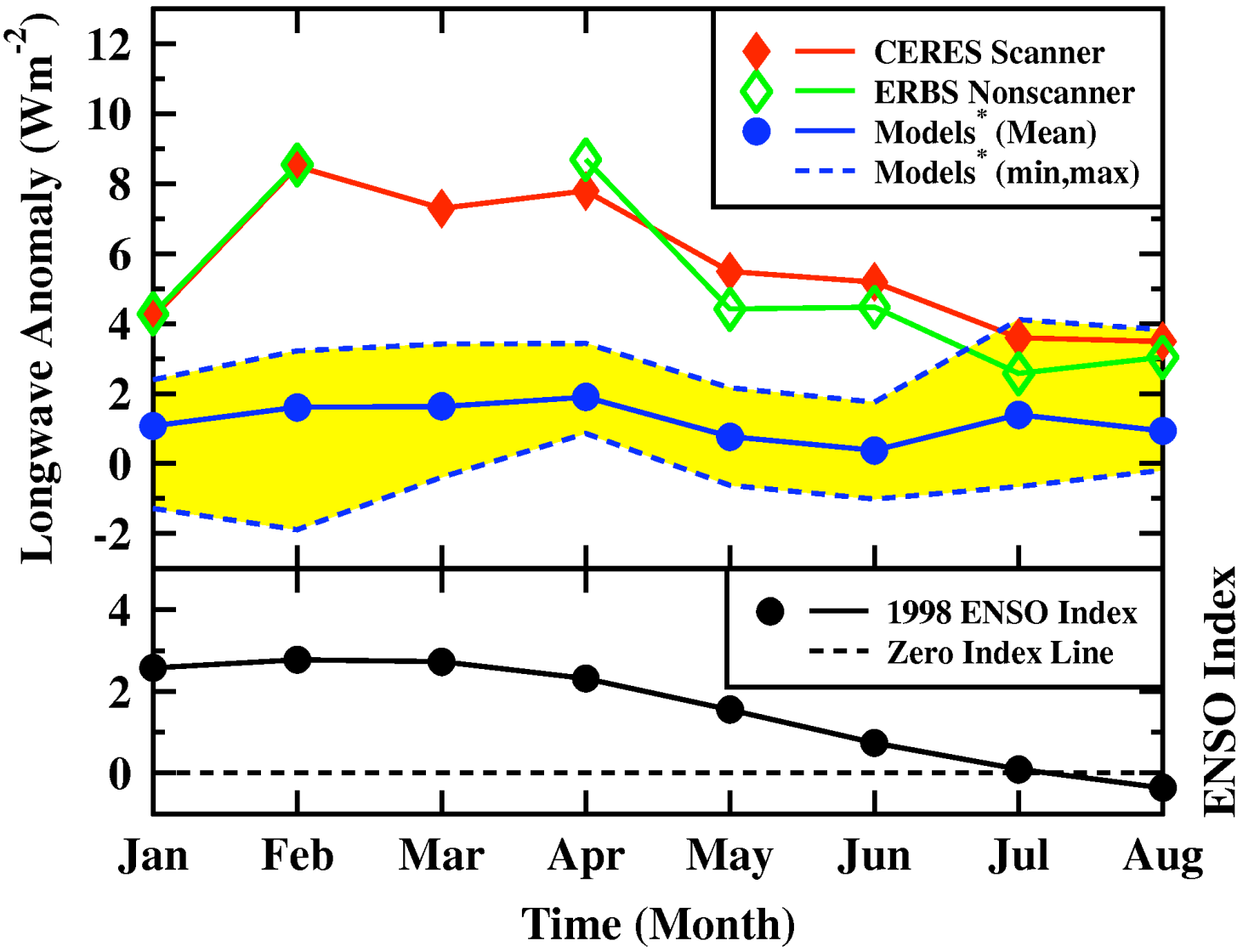


NOAA GFDL Experimental Prediction Model



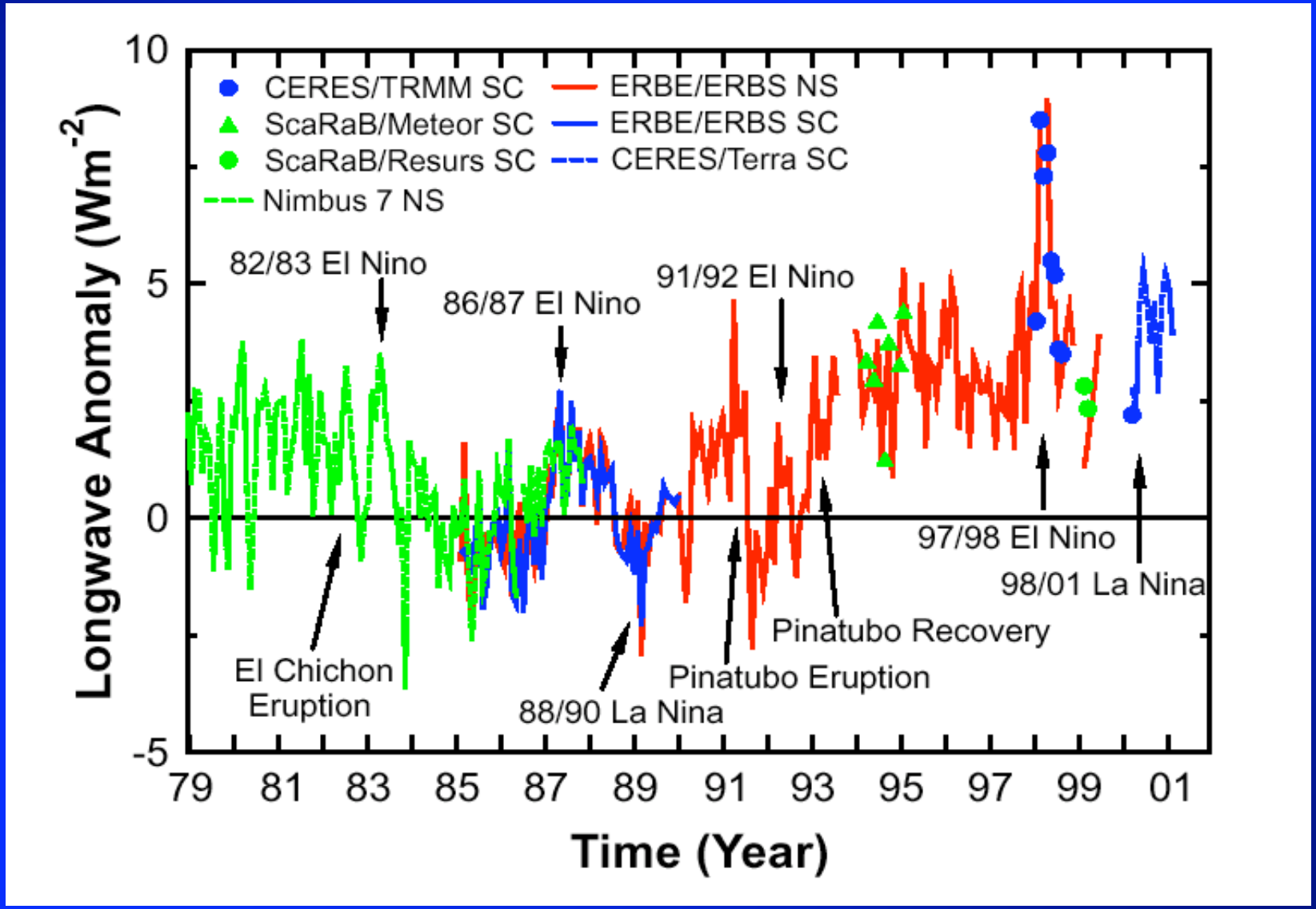
1998 El Nino Tropical Mean (20S - 20N) Longwave Flux Anomalies

(Anomalies Referenced to 1985 through 1989 Baseline)

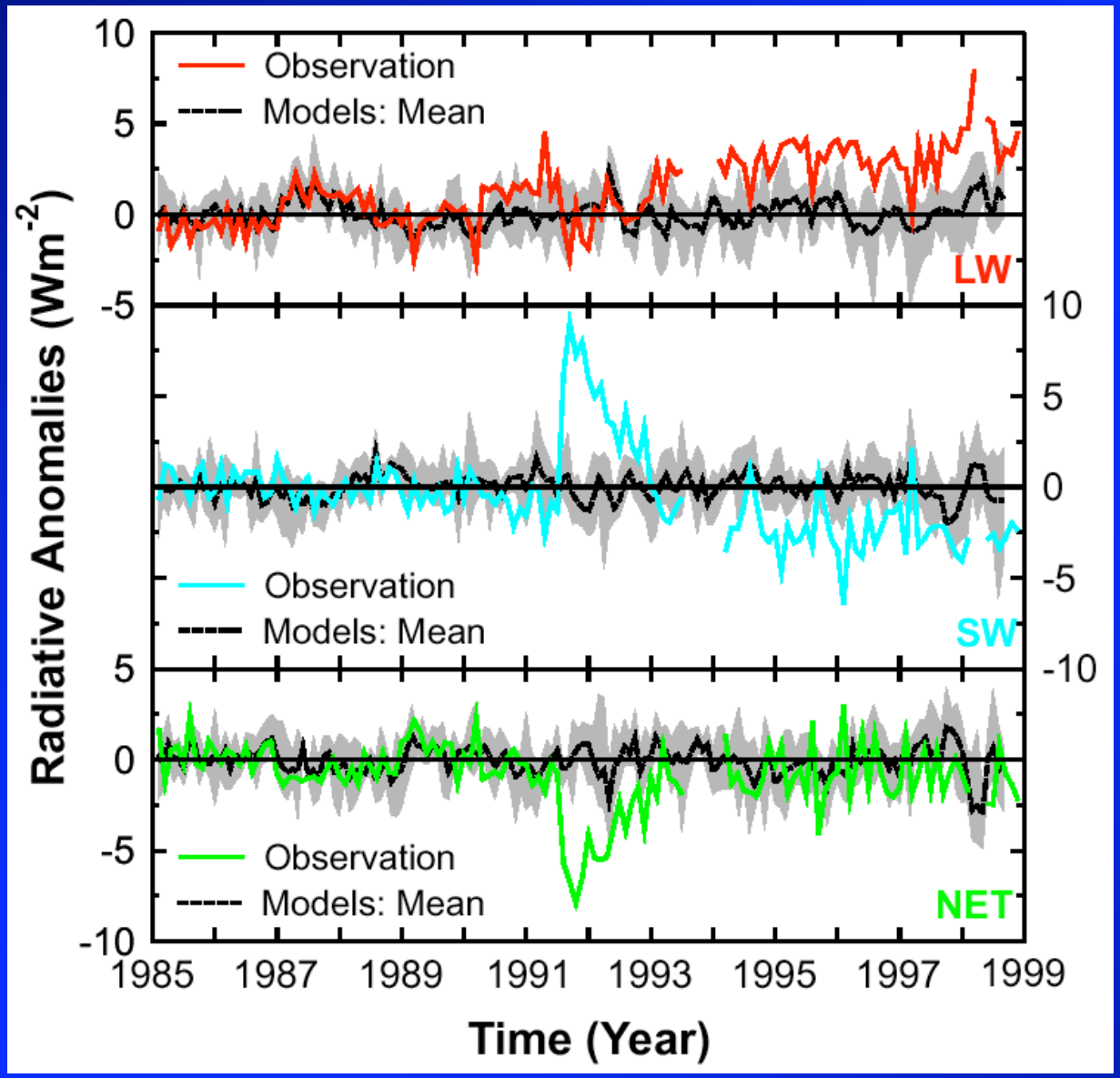


*5 Climate Models and NCEP Re-analysis; All used observed SSTs; Climate Models: NCAR-CSM (Kiehl) UKMO (Allan, Slingo), GFDL and GFDL-EP (Soden, Gordon), CSU (Randall)

An overlapping Earth radiation climate record: 22 years from Nimbus 7 to Terra.



Comparison of Observed Decadal Tropical Radiation Variation with Current Climate Models



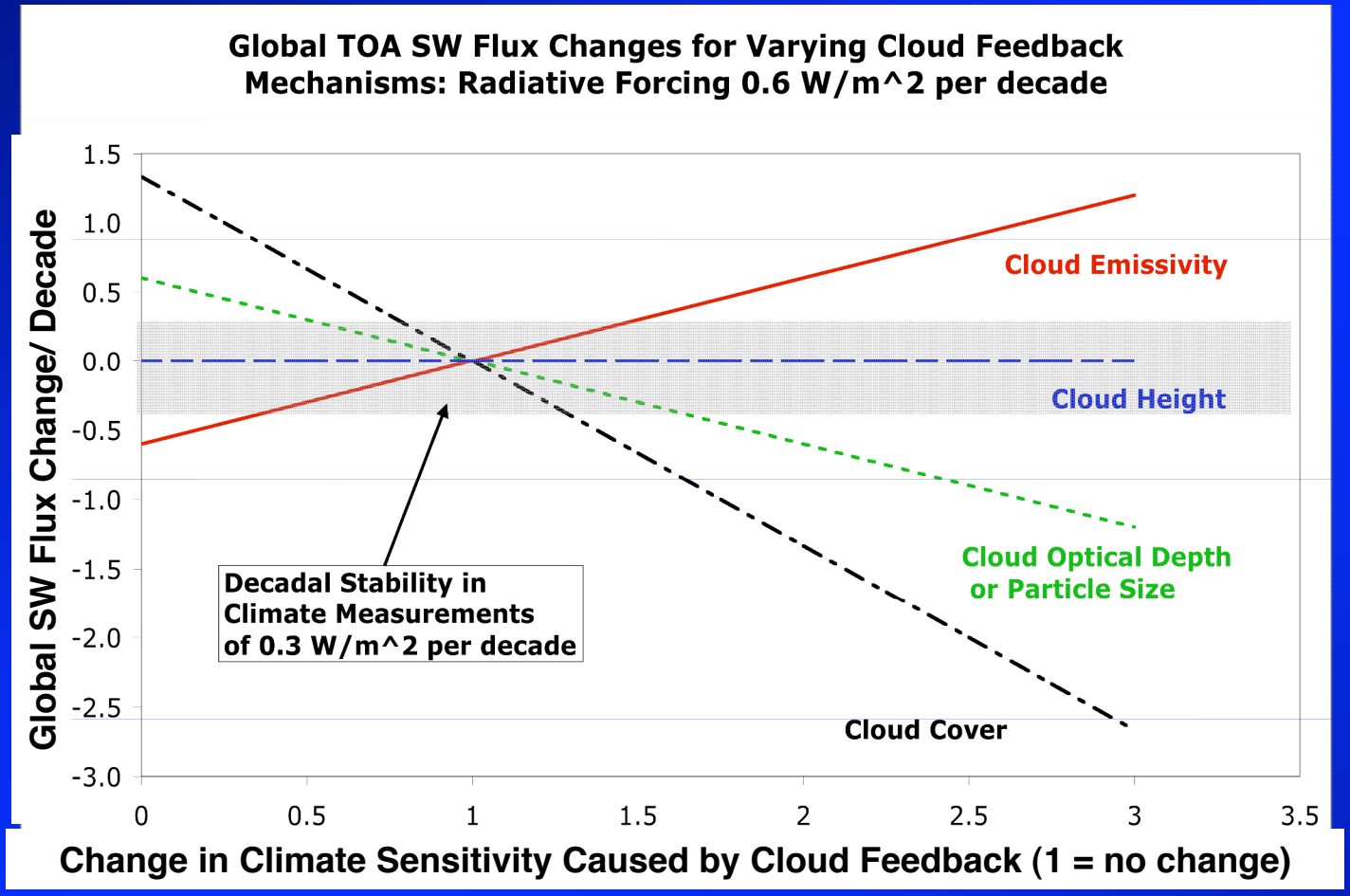
LW:
Emitted Thermal Fluxes

SW:
Reflected Solar Fluxes

Net:
Net Radiative Fluxes

Models less variable than the observations:
- missing feedbacks?
- missing forcings?
- clouds physics?

How accurate to constrain equilibrium global cloud feedback?



- Regional changes will be larger: but no regional "constraint" and global mean still must be accurately known for global feedback.
- UKMO ensemble climate noise for annual tropical mean SW and LW fluxes ~ 0.3 Wm^{-2}: this might be a reasonable lower limit on accuracy.

Global Heat Storage in the Ocean much more variable than previously believed

Figure 5

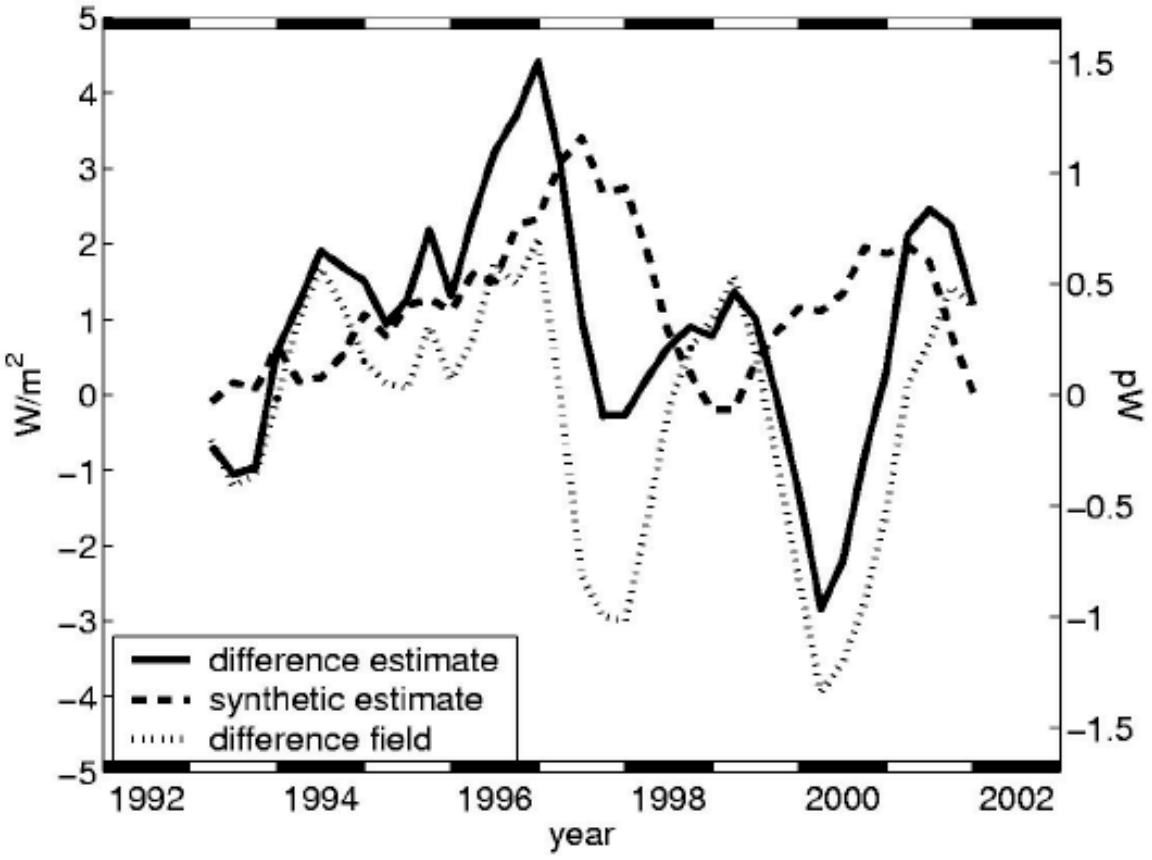
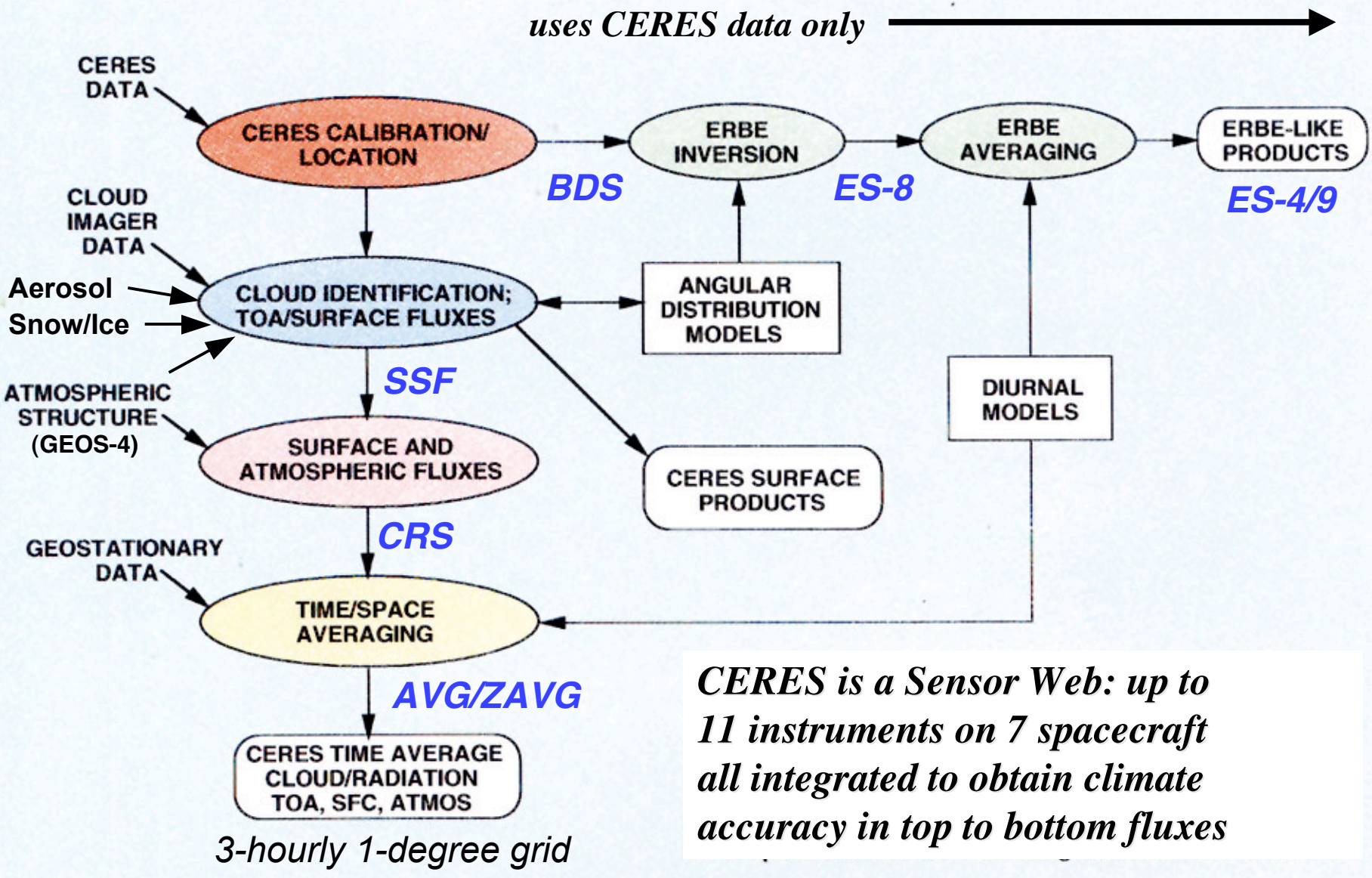


Figure 5. Globally averaged heat uptake variability. The thick black line is the difference estimate. The dashed line is the synthetic estimate (altimetric height multiplied by regression coefficients). The dotted line is the difference field.

Willis et al., submitted to JGR 2003 based on ocean altimeter, and in-situ temperature/salinity profile data

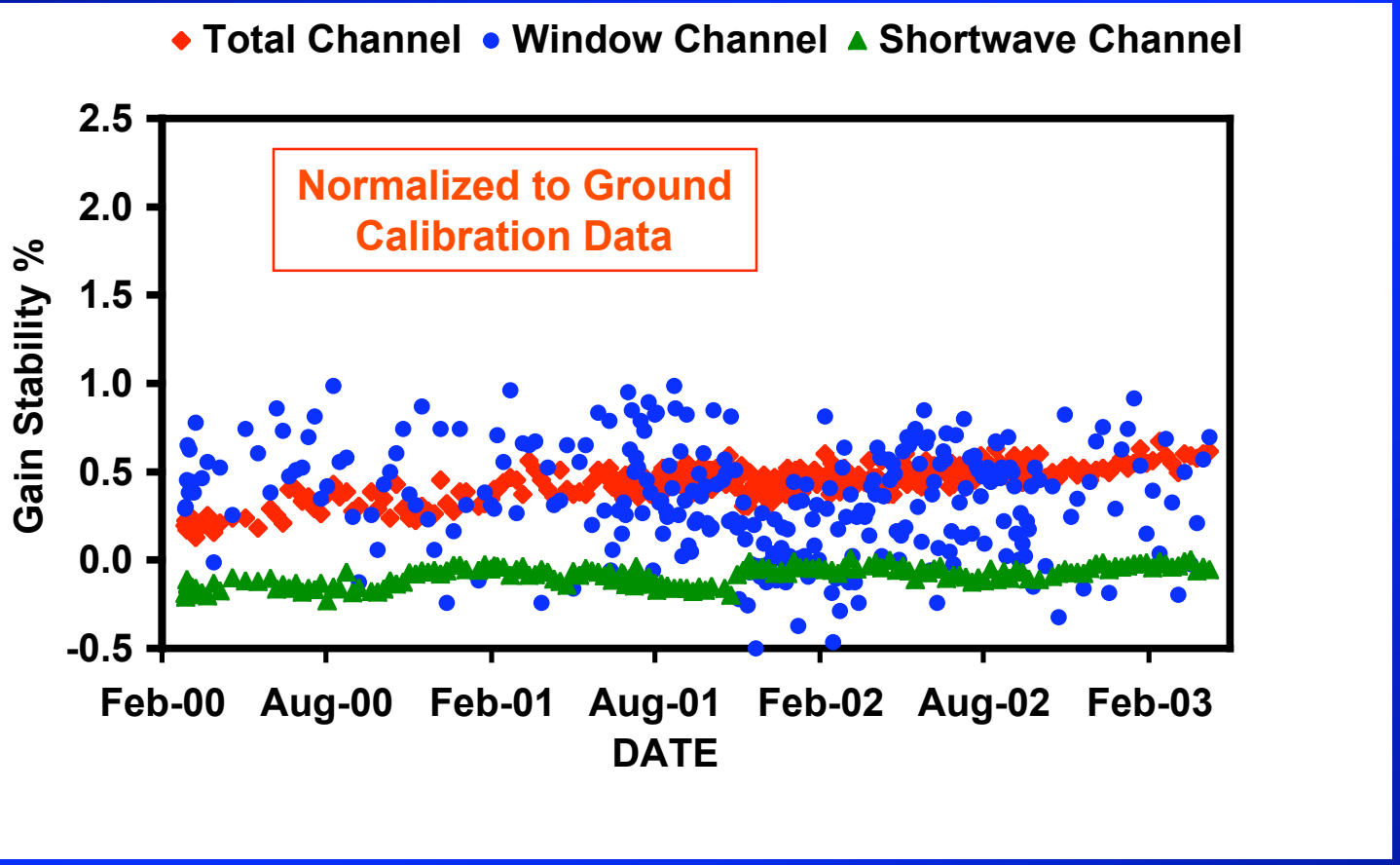
CERES DATA PROCESSING FLOW



CERES is a Sensor Web: up to 11 instruments on 7 spacecraft all integrated to obtain climate accuracy in top to bottom fluxes

Terra/Flight Model 1
Lifetime Radiometric Stability

Determined with the Internal Calibration Module



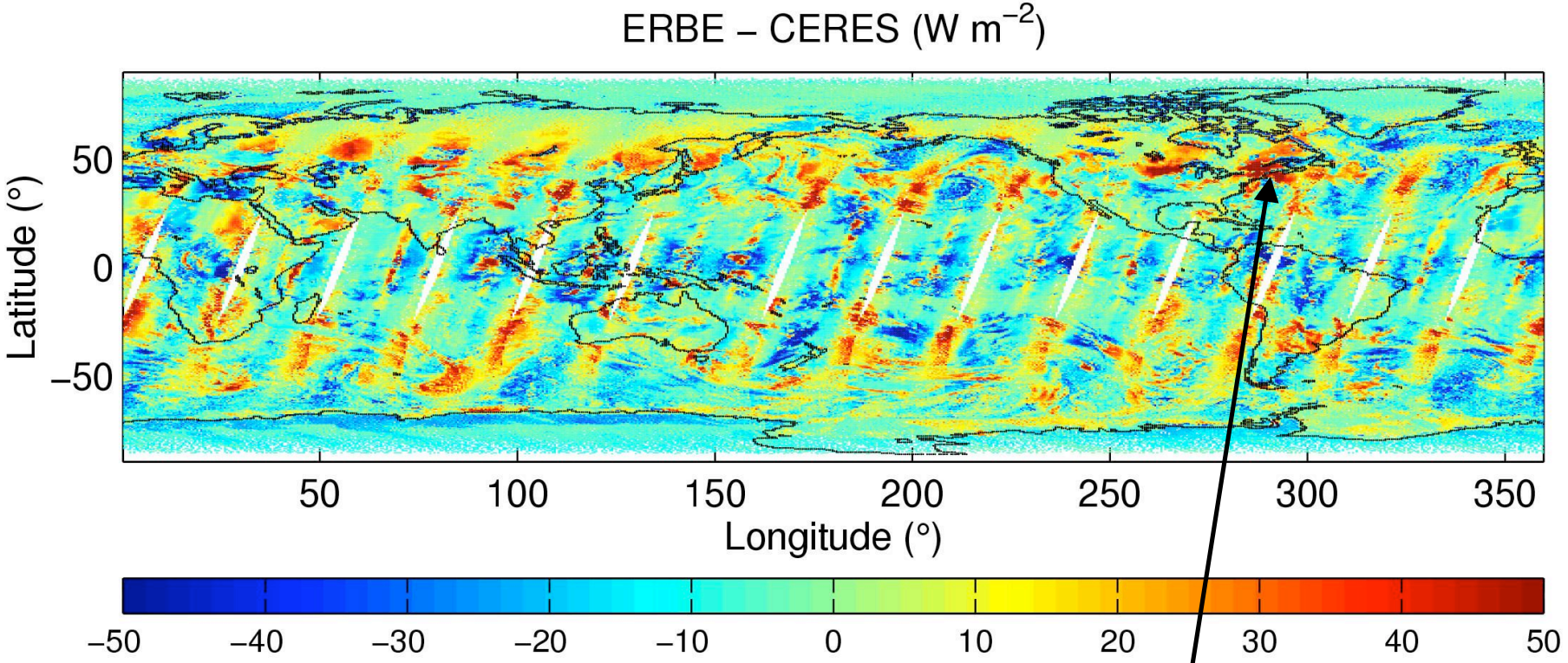
Absolute Calibration:
0.5% LW
1% SW
1% Window

Stability Goal:
better than 0.5% per 5 years

While changes accounted for in CERES processing, ideal situation is change < 0.1% per mission.

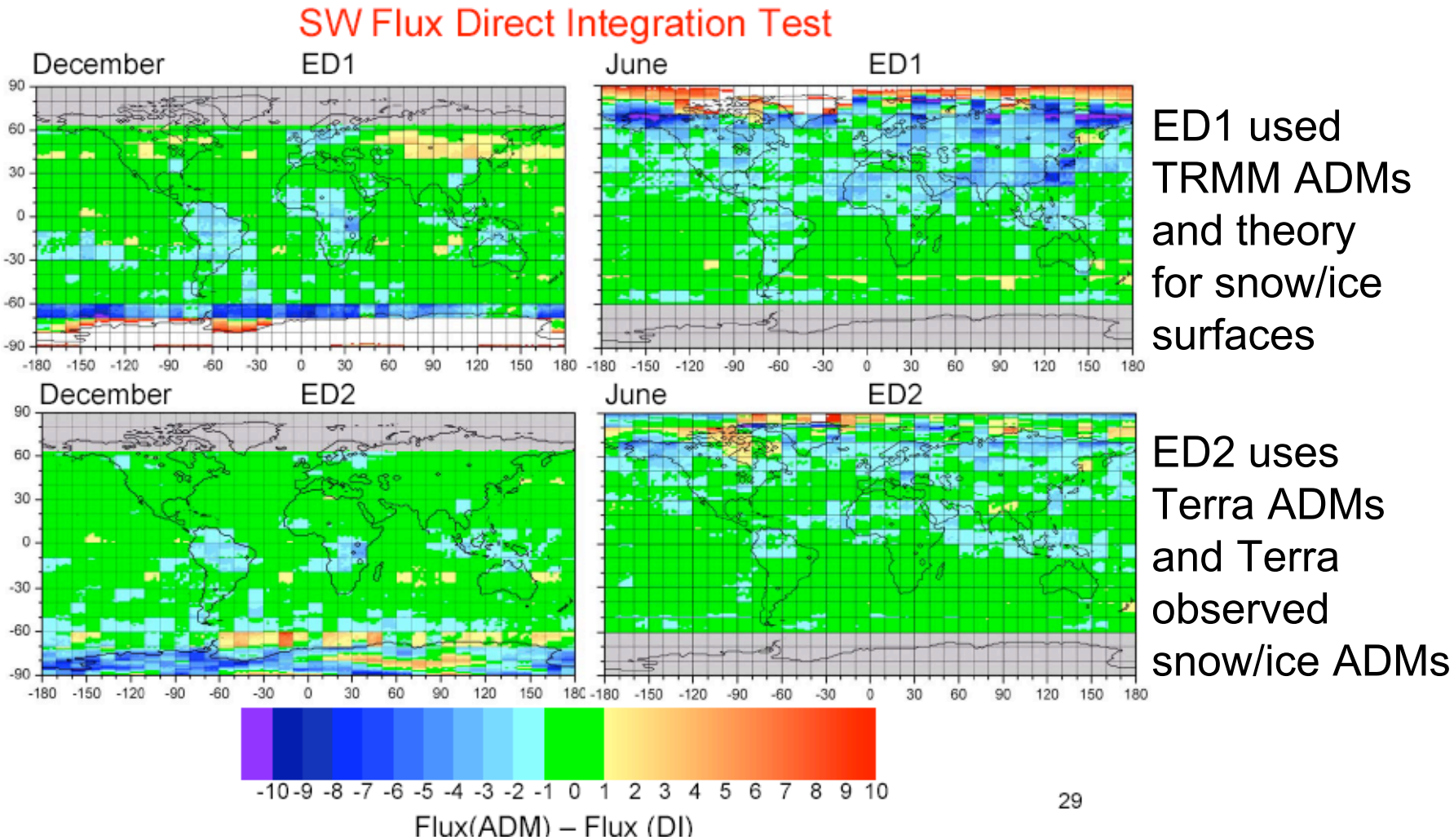
New CERES ADMs greatly improve instantaneous fluxes

Key to constraining more accurate surface fluxes
Key to accurate cloud fluxes by cloud type
Key to accurate matched satellite/surface fluxes for aerosol absorption



CERES TOA instantaneous shortwave fluxes differ from ERBE by +/- 50 Wm^{-2} with a strong dependence on scene type & viewing angle

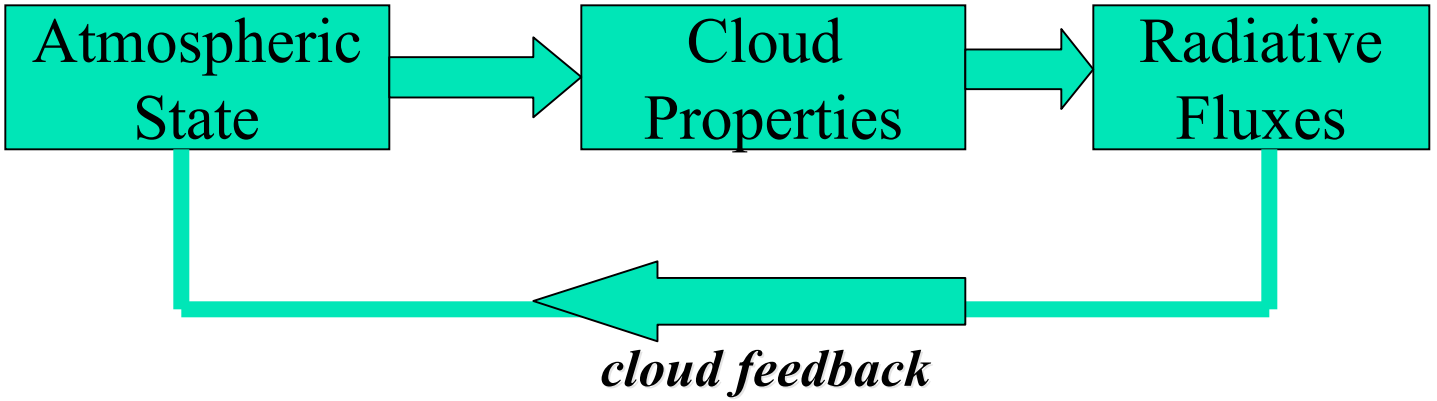
Use CERES Rotating Scanner hemispheric scans over two years to verify climate accuracy (large ensemble biases in new angular models: direct hemispheric radiance integration over 2 years provides truth. Factor of 2 to 10 improvement relative to ERBE. Edition 2 (ED2) are Terra ADMs used in new Edition 2 CERES Data Products



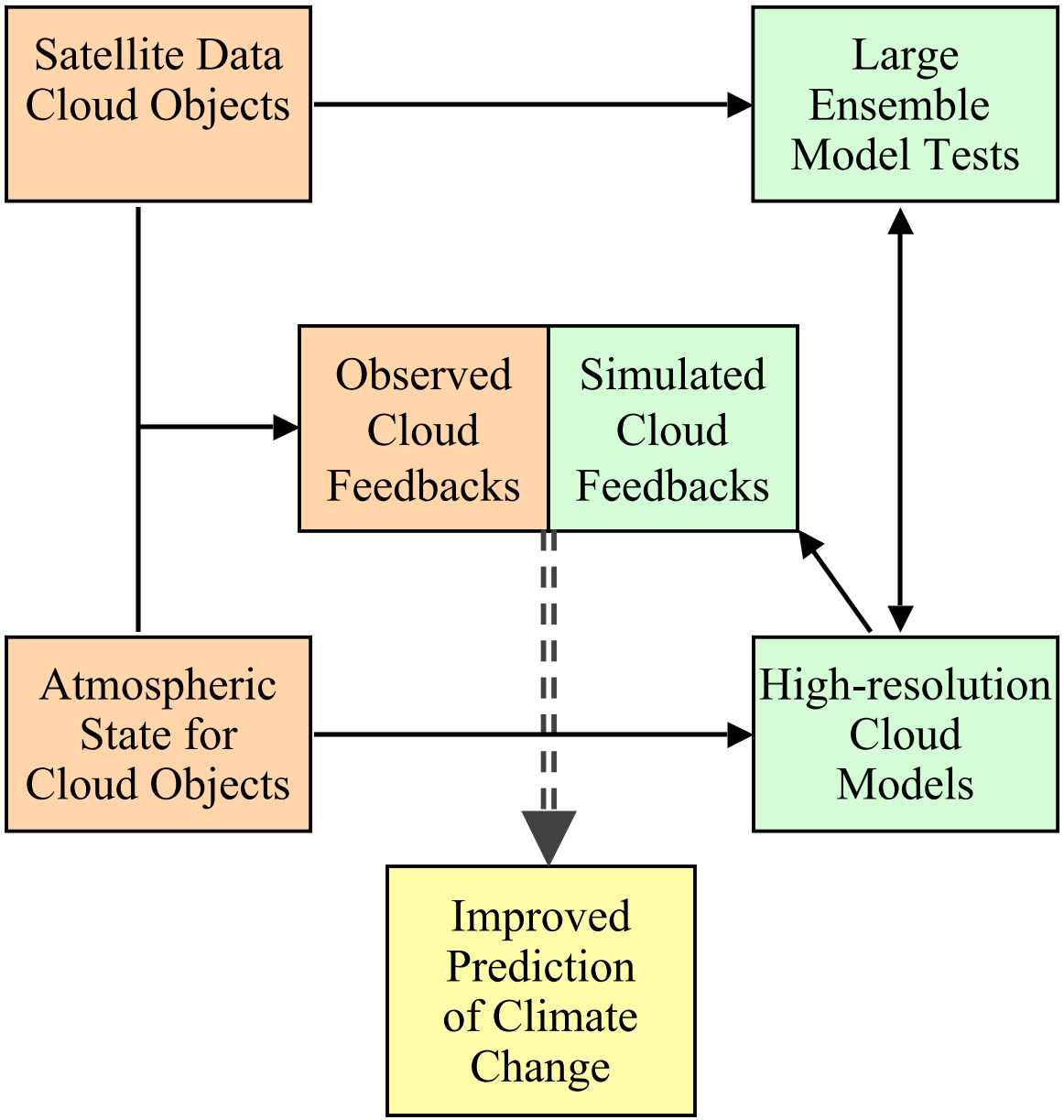
ED1 used TRMM ADMs and theory for snow/ice surfaces

ED2 uses Terra ADMs and Terra observed snow/ice ADMs

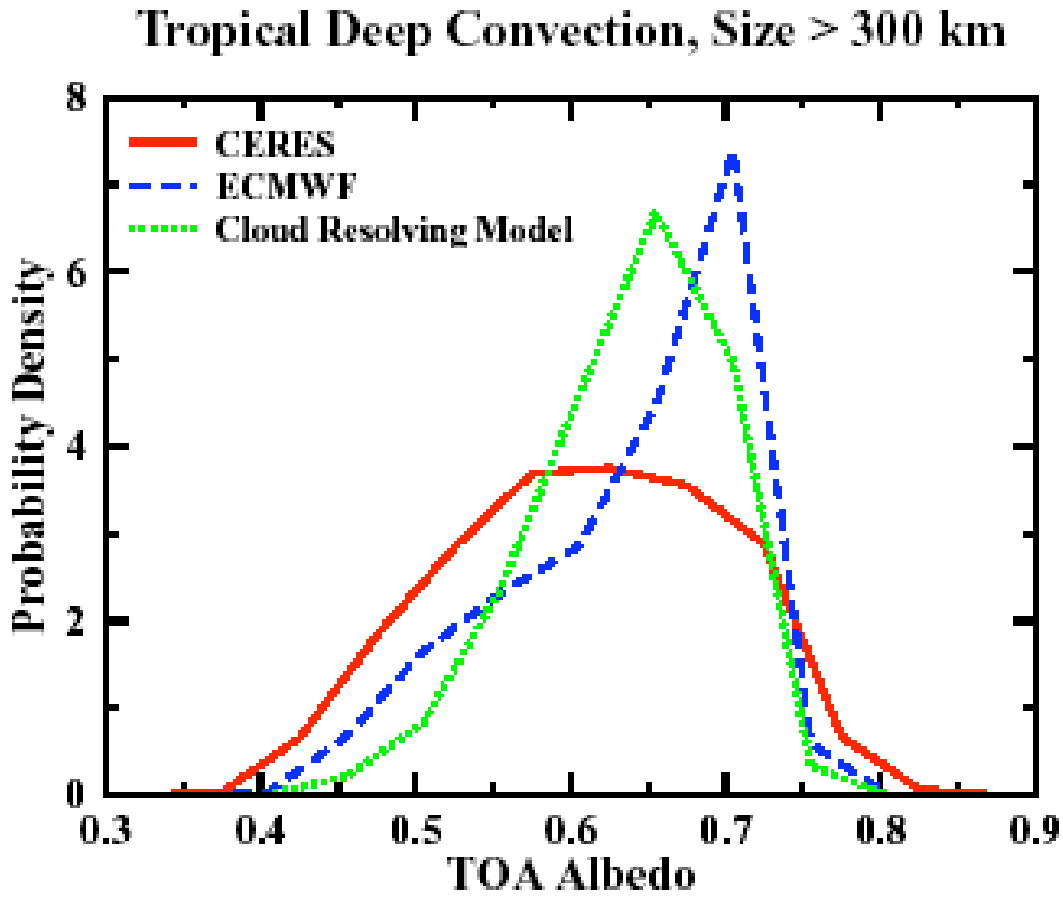
Cloud Feedback



- Nonlinearity of cloud processes requiring observations on all relevant modeling scales (in space and in time)
- Existing methods of cloud model evaluation are incomplete
- Want to unscramble feedbacks by cloud type and partial derivatives of cloud property/flux per change in atmospheric state

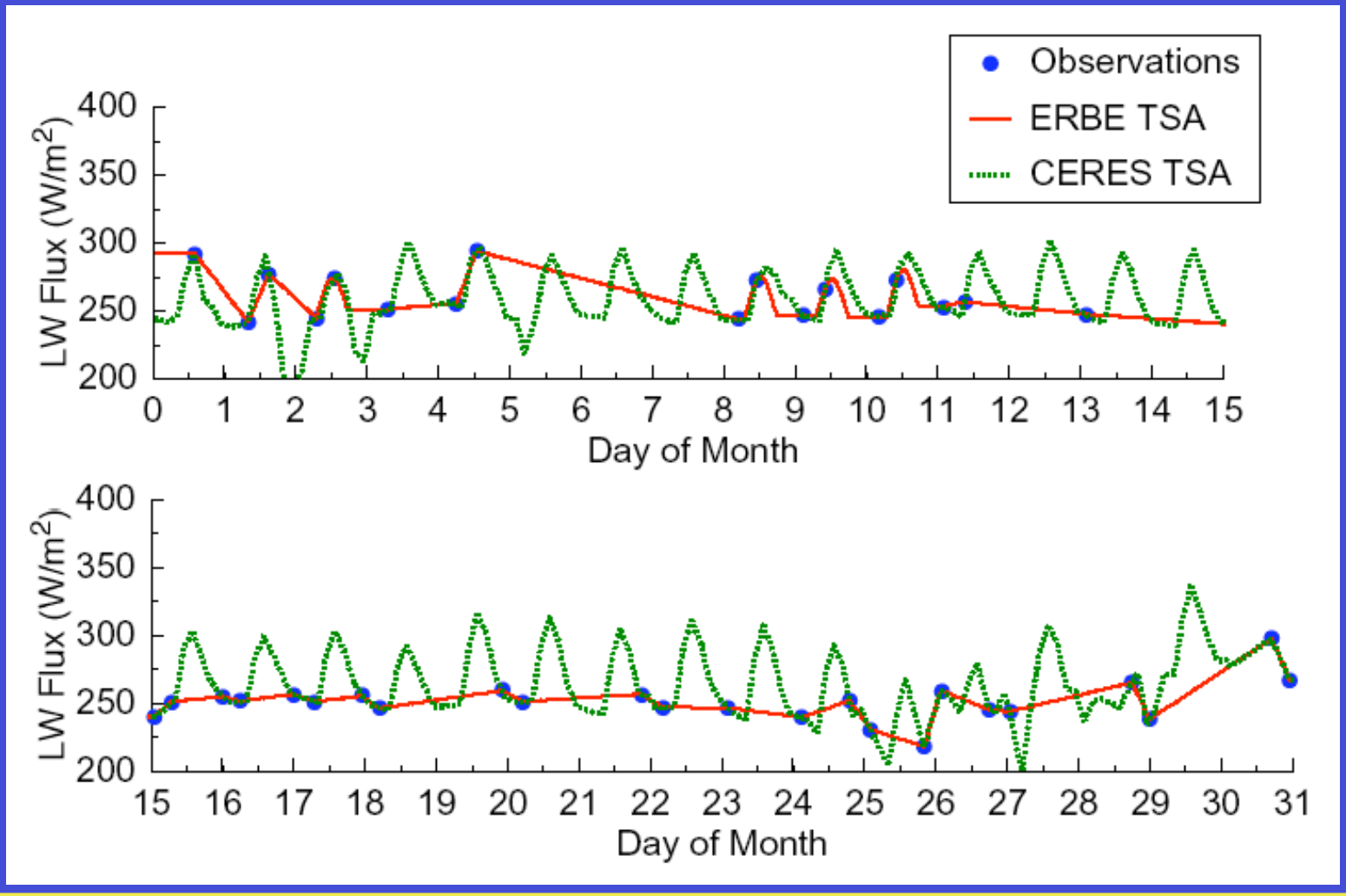

Satellite Data
Cloud Objects
Large
Ensemble
Model Tests
Observed
Cloud
Feedbacks
Simulated
Cloud
Feedbacks
Atmospheric
State for
Cloud Objects
High-resolution
Cloud
Models
Improved
Prediction
of Climate
Change

Using CERES SSF Data with new ADM fluxes by scene type to test climate and cloud resolving models. Probability density function is from ~ 30 large tropical deep convection systems: Global model clouds too bright, 2-D cloud resolving model removes about 1/2 of bias. An example of super-parameterization improvement. Key for A-train data use.

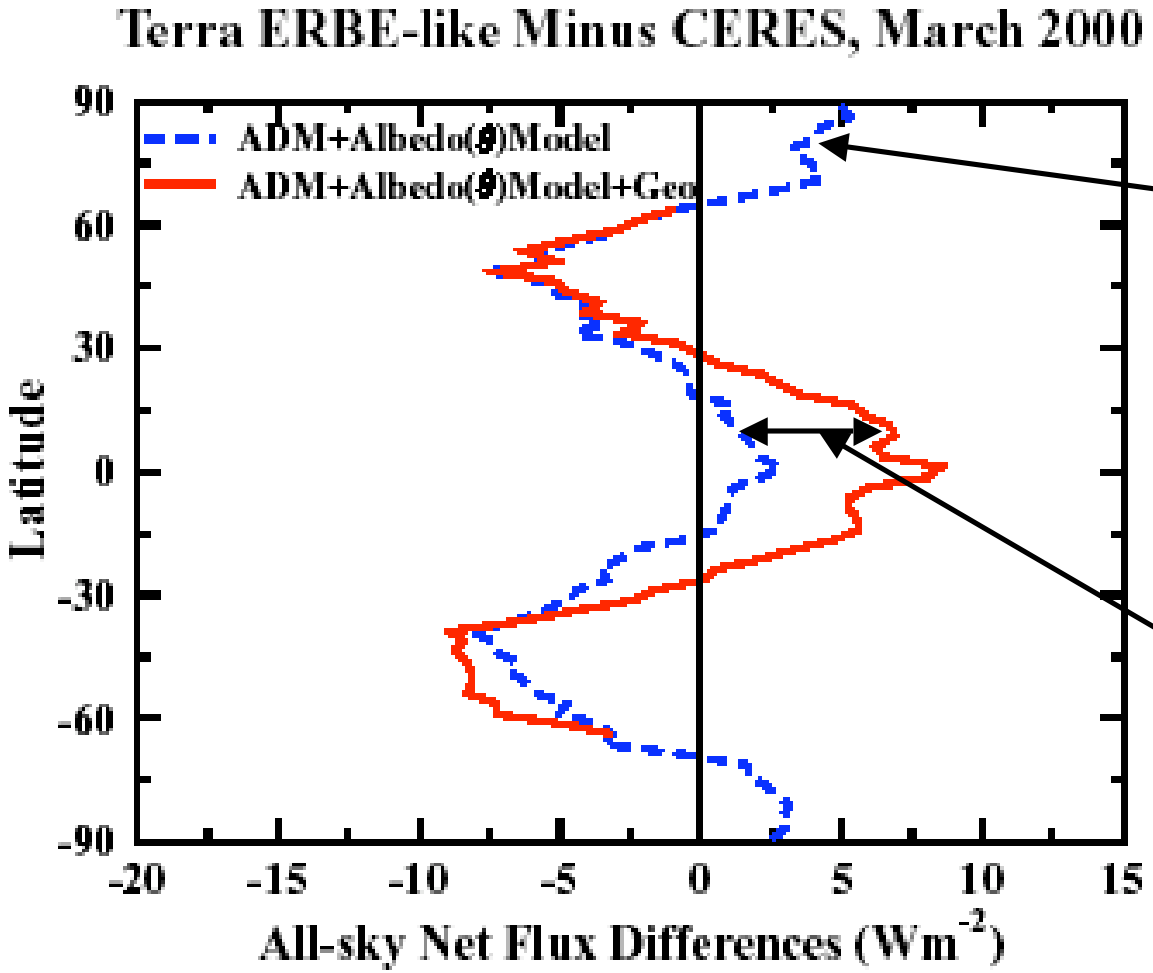


Temporal Interpolation of TOA LW Flux

January 1998 E. Sahara 24.5N 20.5E



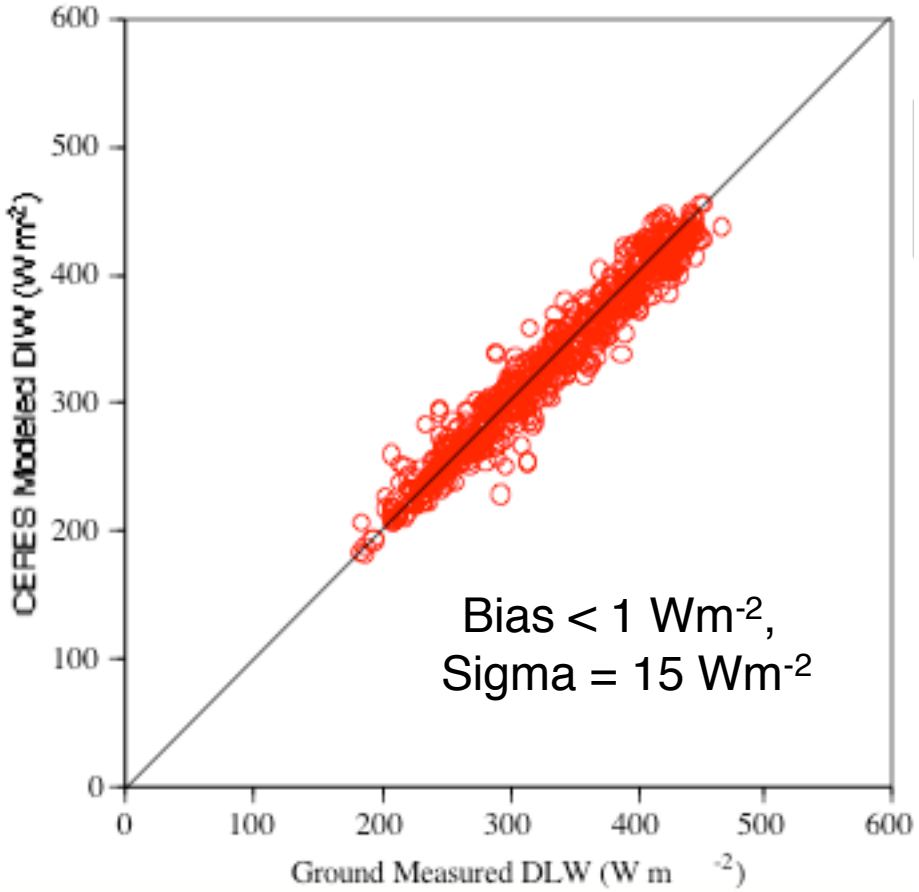
Differences of new CERES SW fluxes from ERBE-Like zonal means for March 2000. Differences up to 8 Wm^{-2}.
Will impact equator to pole transport, surface flux constraints with ARGO on ocean mixing processes, climate model validation



New ADM Impact

New Geo 3-hourly sampling impact

ARM Central Facility, Downward LW Fluxes
CERES estimate (y-axis) vs ARM Surface Measurement (x-axis)
All-sky, 715 CERES Overflights within 1 minute,
Day and Night Overpasses, Nov 00 to Sep 01



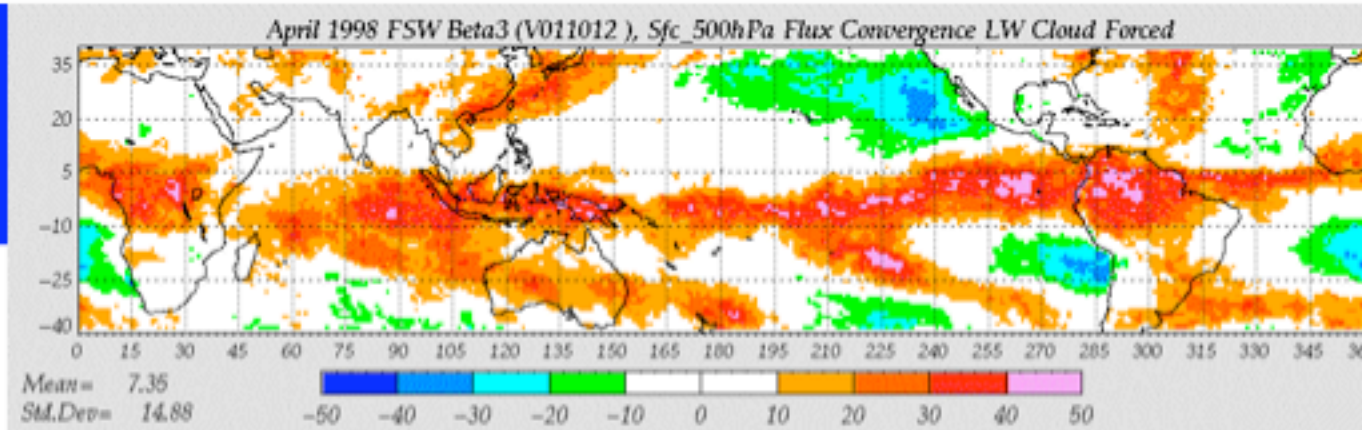
For BSRN sites
equator to pole
Bias < 5 Wm^{-2}
Instantaneous
sigma 15 to 25 Wm^{-2}

Total of 60,000
comparisons

Cloud Forcing

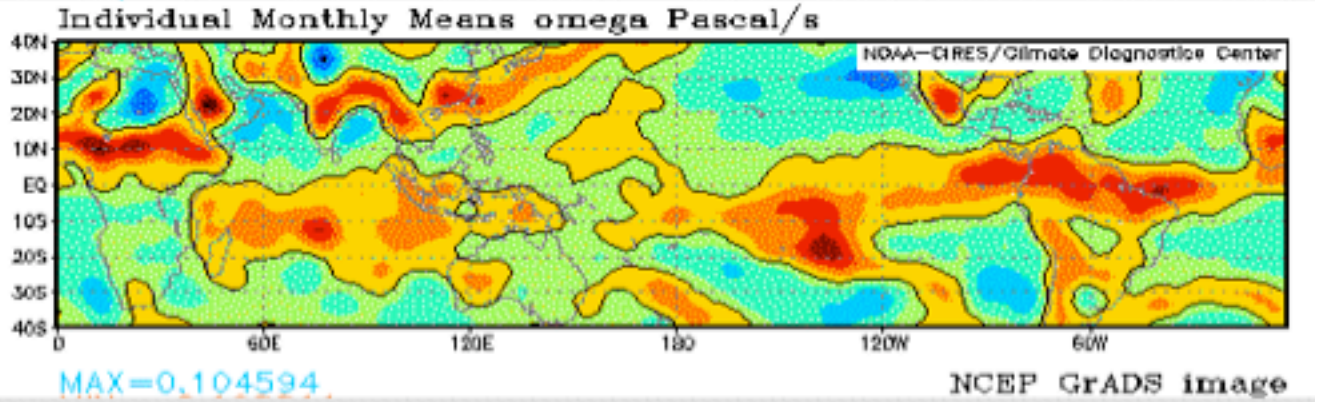
LW Conv Sfc-500hPa

range -50 to +50 Wm-2



Omega 700 hPa

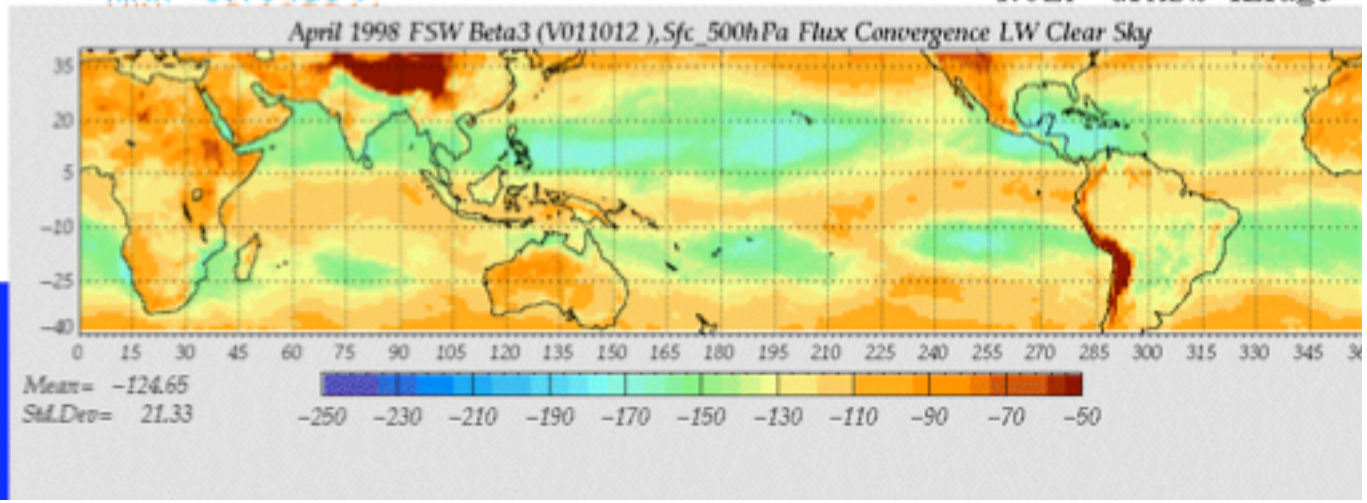
red = ascent



Clear Sky

LW Conv Sfc-500hPa

range -150 to -50 Wm-2



There's a lot going on here: how do I put it in perspective?

- Earth Radiation Budget is an 8-dimensional sampling problem
  - x, y, z, t, λ, Θ_o, θ, ϕ
  - fortunately this is 3 less than string theory....
  - to go beyond ERBE we attack the problem with multiple data sets:
    - CERES broadband and calibration: λ
    - CERES cross-track scan: x,y
    - CERES rotating azimuth plane scan/ADMs: Θ_o, θ, ϕ
    - CERES TRMM: full Θ_o range
    - Geostationary: t
    - MODIS imager cloud/aerosol (later A-train): z

- Merging these data/processes is analogous to coupling ocean/atmosphere/land physics in a coupled climate model:
  - more capability but more challenges: especially interfaces
  - we want to avoid "flux adjustments"

CERES 8-dimensional Approach

- New generation of global surface, atmosphere, TOA fluxes.
- Use two complementary approaches to catch problems:
  - A) Minimize radiative transfer theory: SRBAVG product
  - B) 8-D assimilation for radiation: analogous to 4-D dynamic assim.
    - Use radiative transfer theory but constrain to observations
  - C) As in B) but add CALIPSO and Cloudsat vertical cloud and aerosol layering profiles. Use for validation of B) globally and test advanced passive imager/sounder/microwave multilayer cloud
- CERES is through process A) in 7 of the 8 dimensions. Working out the final kinks in merging with geo for time sampling (Terra tougher than precessing TRMM orbit)
- Expect to have process A) SRBAVG gridded data by summer for 4 years of Terra global data. TOA & Sfc Fluxes, Cloud Properties and Aerosols matched in time/space to fluxes.
- Expect process B) SYN/AVG gridded data to beta in late 2004 and validated Edition in mid to late 2005.
- Expect process C) AtrainCRS beta product in mid to late 2005, and validated by mid to late 2006.

What about global net fluxes?

- ERBE was about 5 Wm^{-2} (heating) and was within its accuracy bound given calibration, angular sampling, and time sampling limitations
- CERES is reducing all major error sources and has a target uncertainty of about +/- 2 Wm^{-2} in global net.

	SW	LW
– calibration (absolute accuracy)	+/- 1.0	+/- 1.0
– spectral correction	+/- 0.1	+/- 0.1
– spatial sampling	0	0
– angle sampling (new ADMs)	+ 0.5	- 0.1
– improved reference altitude (20km)	+/- 0.1	+/- 0.2
– twilight shortwave flux (adds 0.25)	+ 0.1	0
– spherical earth near sunset/sunrise	< + 0.7	0
– cloud optical depth biases (solar zenith albedo)	+ 0.7	0
– new solar constant (1361 vs 1365)	+ 1.0	0
– time sampling (geo calibration aliasing)	+/- 0.4	+/- 0.1
– ocean heat storage constraint (2000/2001)	0.3 to 1.0	
– expected range in current SRBAVG product global net for 2000/2001:	2 to 6 Wm^{-2}	

What about global net fluxes?

- Ocean Heat Storage variability:
  - Recent submitted paper on merged in-situ/altimeter heat storage for 1992 to mid-2002.
  - Interannual variations: 1 +/- 2.5 Wm^{-2} global mean
  - Single year annual sampling noise: 1.3 Wm^{-2} 1-sigma
  - 10 year average sampling noise: 0.2 Wm^{-2} 1-sigma
  - Completion of ARGO should cut errors in half (southern oceans)

- What is CERES interannual uncertainty in net flux year to year?
  - Calibration stability dominated: ~ 0.1 to 0.2 Wm^{-2}.
  - Global annual net Terra ERBE-Like first 3 years:

Time Period	TOA Net	In-situ/Altimeter	Altimeter
Mar 2000 - Feb 2001:	3.95	-1.4	1.5
Mar 2001 - Feb 2002:	4.69	2.1	1.2
Mar 2002 - Feb 2003:	4.93		

What about decadal variability?

- Tak Wong will give an update relative to the tropical variability as seen in other data sets:
  - ISCCP
  - Surface Observer Cloud
  - Correction of ERBS altitude drop: decreases magnitude of LW anomaly (3 to 1.5) but increases SW (-3 to -3.7) and Net anomaly (from near zero to heating of about 2 Wm^{-2} more in the 90s).

- Next step is combined Terra/Aqua ERBE-Like to handle the diurnal cycle. We now have a year of it and can compare to ERBS/NOAA-9 data and soon the Terra SRBAVG data:
  - All-sky, Clear-sky, Cloud Radiative Forcing
  - SW, LW, Net
  - Zonal/regional/global

What Data is Currently Available?

- **Validated Products (science ready, data quality summary avail.)**
- **Beta Products (typically available but not validated/science ready)**

Product *Time Period*	TRMM *1/98-8/98 and 3/00*	Terra *3/00 forward*	Aqua *7/02 forward*
Instantaneous Field of View Products			
ERBE-Like ES-8	9 months	3.5 years	1.5 years
ADMs	yes	yes	spring 05
SSF: (TOA/Sfc/Cld/Aer)	9 months	3 years	fall 04
CRS (TOA/Sfc/Atm/Cld/Aer)	9 months	1 year	fall 04
1 Degree Gridded Monthly Products			
ERBE-Like ES-4/9	9 months	3.5 year	1.5 years
SRBAVG (SSF + geo)	9 months	July, 04	spring 05
AVG (CRS + geo)	spring 05	summer 05	fall 05

(note: 1 degree gridded SSF is SFC, and gridded CRS is FSW product)

Where do I get the data?

- CERES Data Can be Ordered on-line through the Atmospheric Sciences Data Center at NASA Langley Research Center (URL: http://eosweb.larc.nasa.gov/)

- Each Data Product has a Data Quality Summary: dynamic summary of current understanding of accuracy and limitations (journals are too slow).

- All Data Are in HDF Format and Can be Viewed using CERES ViewHDF Software (works on Mac, PC, SGI, Sun)

- Documentation Can be Found at the CERES Website (URL: http://asd-www.larc.nasa.gov/ceres/ASDceres.html)